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Use of Remote Sensing For Land Use Policy Formulation

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Michigan State University

East Lansing, Michigan 48824

USE OF REMOTE SENSING FOR LAND USE POLICY FORMULATION

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USE OF REMOTE SENSING FOR LAND USE POLICY FORMULATION

FOREWORD: Scope of Report

This report is a summary description of the activities carried out during the second half of the 1976-77 grant year from December 1, 1976 through May 31, 1977 by the research participants in the Michigan State University Remote Sensing Project. It is a continuation of the Semi-Annual Progress Report, dated February 23, 1977 which covered the period June 1, 1976 to November 30, 1976.

A C K N O W L E D G E M E N T S

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I N T R O D U C T I O N

The problems of land and water resource use, misuse, and debilitation continue as one of the primary areas of urgent concern for the people of Michigan and the United States. Action programs are required for remedying accumulated abuses and mismanagements; for preserving and conserving the environmental resource qualities remaining. Effective programs can only be formulated by a broad community of scientific disciplines and by the energies and actions of many public and private institutions. A prerequisite to the formulation and acceptance of any effective action program is the ready availability of accurate and timely information for the formulation of policies which can be quickly translated into combinations of short term and long range remedial and preventative programs. Remote sensing is now becoming recognized and acknowledged as a major technological means for providing this kind of information. The MSU Remote Sensing Project has been playing a major role in bringing this change about in Michigan.

The primary objective of the Project is to work with agencies at all levels of government in Michigan, as well as with private organizations, to develop a wide diversity of applications of remote sensing for improving land/resource use decisions and actions. To realize this objective, Project activities are aimed at improving, across the board, the process of analyzing and allocating land and resource use in Michigan and eventually developing a responsible and self-supporting community of users of remote sensing in the state. To accomplish these aims Project staff conduct demonstration applications of remote sensing, provide user services, and participate in educational activities.

The following presentation describes in summary fashion the principal activities engaged during the December 1, 1976 to May 31, 1977 portion of the grant year. For reporting purposes, the activities are grouped under three broad headings: (A) application activities, (B) service activities, and (C) contract activities.

A. APPLICATION ACTIVITIES

This section reports on applications of remote sensing to selected natural resource situations and problems for which base data could be quickly located, identified and evaluated using remote sensing technology. The problems selected were ones for which program implementation and/or improvements in the quality and effectiveness of on-land actions could occur.

Some of these applications initially demanded considerable Project input. When rendered operational, these were gradually transferred to appropriate agencies for continuation or development to more advanced stages which would lead to subsequent actions. Others are expected to return to command Project attention from time to time when new information might be determinable or when additional decisions will need to be made regarding on-land applications.

A1. Mosquito Control in Saginaw and Bay Counties

Saginaw-Bay Mosquito Control Commission
1416 South River Road
Bay City, Michigan 48706

The 1975 outbreak of St. Louis Encephalitis transformed the mosquito problem in Michigan from a nuisance to a potentially major health hazard. Comprehensive control measures however have been hindered by the absence of officially designated and funded agencies to deal with the problem.

An innovative method of breaking this deadlock was formally put into operation for two east central Michigan counties in January, 1977. The Saginaw-Bay Mosquito Control Commission (SBMCC) was established as a private non-profit corporation for the control and abatement of mosquitoes and the diseases borne by mosquitoes. This organization which is funded through a county millage has a three year period to establish an effective eradication program, and an essential prerequisite for eradication is surveillance of potential disease vector sites. The executive director of the SBMCC has estimated that traditional ground survey methods for this surveillance would require three to four years to complete with a staff of eight to ten individuals participating.

Discussions with SMBCC staff suggested that remote sensing data sources would be essential in the preparation of an inventory of mosquito habitats. It was decided initially that three categories of information would be provided: 1) Forested Wetlands, 2) Open Wetlands and Marshes, and 3) Residential Areas.

Maps of Saginaw and Bay Counties were made showing Forested Wetlands, Open Wetlands and Marshes, and Residential Areas. The mapping was done directly from high altitude imagery (NASA, RB-57, May 13, 1975, CIR), at a scale of approximately 1:120,000, onto acetate overlays. Similar imagery was available for July 1, 1975 and was used during the interpretation for comparative purposes. The primary information came from the spring imagery because at this time water levels were at their highest and tree foliage did not obscure the ground scene. Diazo copies of the interpreted and delineated acetate overlays were supplied to the SBMCC.

In addition, the information from the overlays was reduced to a scale of 1:175,000 and transferred to standard County Highway maps. These maps and a 35mm slide of each map was also supplied to the SBMCC. The characteristics of each category are briefly described below:

1. Forested Wetlands. The forested wetlands are defined as those forest areas which are seasonally wet. Spring imagery recorded pre-leaf out conditions so that wet areas with high levels of soil moisture or surface water were easily identifiable by their darker hue. These areas were for the most part not separable from other forested areas on the July imagery because of tree foliage and soil water losses. Forested river bottoms and ponds within forested areas were also delineated. These areas provide a breeding site as well as a habitat for adult mosquitoes.

2. Open Wetlands and Marshes. Areas of open water were identified from the imagery and verified using 7.5' and 15' U.S.G.S. topographic maps to examine for a recorded water body or closed depression. It was a wet spring in 1975 and many of the open water bodies were seasonally flooded. Man-made areas of open water bodies such as sewage treatment lagoons, water hazards on golf courses and ponds along major highways were included in this category. River floodplains that were inundated on the spring imagery were included as open wetland. Marsh areas are also primarily open water in the spring. These features were distinguished by the presence of emergent vegetation on the July imagery. The delineated areas were checked against 7.5' and 15' U.S.G.S. topographic maps to verify that all the areas on the maps marked as swamp were also included on the overlays. If there was a discrepancy the final decision was based on imagery interpretation.

3. Residential. Residential areas were classified as contiguous groupings of 20 or more single or multiple family dwellings either in a strip or subdivision configuration. Strip development includes dwellings in a single strip, those that are

staggered on both sides of a road and short strips heading in more than one direction at a road intersection. Mobile home parks with 20 or more residences were also included. Urban areas were delineated as contiguous blocks thus industrial, commercial and open space areas were not separately indicated.

The residential delineations were made so that the SBMCC could concentrate their initial spraying efforts in the more densely populated areas. These overlays can also be used in conjunction with either of the other two to see the relationship between residential (or non-residential) areas and mosquito problem sites.

In mid-May 1977 a light plane flight provided imagery of Crow Island and critical areas in St. Charles Township to the SBMCC. Color infrared 35mm slides were acquired for all the sites and 70mm color photography was obtained over the Crow Island location. This photography provides reference data for the interpretation of smaller scale imagery, particularly NASA high altitude CIR photography and Landsat data.

Commission staff are presently using the maps and copies of the NASA imagery (which they have purchased) in their office to evaluate their response to in-coming complaint calls. The maps are now being evaluated in the field. The commission is concurrently comparing the photo-derived map procedure against more traditional methods of acquiring habitat data (e.g. ground surveys).

In the year ahead we will be exploring ways in which Landsat data can be applied in their program--both through manual interpretation and computer processing (pattern recognition). The emphasis will be on periodic monitoring of specific mosquito breeding habitats via remote sensing and the incorporation of remotely sensed data into a computer-based information and analysis system which will be utilized on an operational basis.

A2. Inventory of Surface Water Accessible to Fire Trucks

Antrim County Planning Department
County Courthouse
Bellaire, Michigan 49615

A major problem in Antrim County is locating accessible water sources for use by fire fighting units. All units reporting to a fire outside of village or city limits have an on-board water supply. When this supply is expended, the unit has to recharge its tanks. The trip to recharge should be as brief as possible and information regarding the nearest accessible water source is crucial.

MSU personnel identified and delineated all surface water areas in Antrim County of at least 0.2 hectares from 1:36,000 color-infrared photography acquired by the Michigan Department of State Highways and Transportation in 1973. The name, type (e.g. natural lake, intermittent stream), size and depth of each water area were recorded based on the classification system given in Table I.

Potential access sites for recharging fire truck water supplies were then identified from the photography. For each identified access site, a determination was made from the photography as to the type of access route, the intervening land cover or land use and possible limitations to recharging such as water depth, the presence of aquatic vegetation or slope restrictions. The ownership of the access sites, as given in the county plat book, was also identified. The accessibility classification system employed is also cited in Table I.

The identification of surface water locations from the photography was accomplished in 1975, and was reported in our Semi-Annual Progress Report, June-November 1975. The project was then delayed because the user agencies, i.e., the Antrim County Planning Department and local fire departments, intended to establish a standard geographical referencing (address) system for the county, which also would be used in the surface water inventory. Such a system never materialized, therefore Project personnel resumed work on the inventory in early 1977.

The locations of water sources and identified access points were transferred to a series of mylar township base maps at a scale of 1:36,000

Table I.--Antrim County Waterbody Inventory: Classification Scheme

Name: The name of the waterbody as given on U.S.G.S. topographic maps or other sources.

Type: All water areas have been classified from the photography as to their origin. Classes of surface water recognized were:

1. Natural lake or pond
2. Natural lake with dam
3. Artificial lake
4. Artificial pond
5. Hydro-electric reservoir
6. Municipal water supply
7. Wildlife flooding
8. Mill pond
9. Gravel pit or quarry
10. Marl lake, dredged
11. Fish hatchery
12. Flooded borrow pit
13. Recharge basin
14. Settling pond
15. Beaver pond
16. Waste treatment pond
17. Fish breeding pond
18. River or creek
19. Intermittent lake
20. Intermittent stream

Size: The area of the lake or the width of the stream or river. The area or width of other waterbodies was estimated from the aerial photography.

Depth: Maximum depth as reported in the Michigan Lake Inventory Bulletin.

Access Type: Type of surface of access route.

1. Paved road
2. Boat landing
3. Dirt road
4. Open field
5. Farm lane
6. Fire land
7. Pipeline
8. Powerline
9. Driveway
10. Private yard
11. Bridge
12. No access

Land Use: The land cover or land use of the access site.

1. Residential
2. Commercial
3. Industrial
4. Water transportation
5. Road transportation
6. Urban open and other
7. Cropland
8. Pasture
9. Orchards
10. Farmsteads
11. Herbaceous rangeland
12. Shrub

Access Ownership: Private or public.

Possible Limitations: Possible limitations to recharging fire truck water supply.

1. Depth--shallow water source, may pose restrictions in dry periods
2. Vegetation--presence of aquatic vegetation may limit pump functioning near the shoreline
3. Wet--site surrounding access point may cause access problems in wet periods
4. Slope--the slope of the access site may cause access problems

(Figure 1). A unique identifier code was assigned to each water source and access point and these codes, along with the corresponding information on water characteristics and accessibility parameters, were recorded on a computer file. This file allows the output of information in various formats and facilitates modifications based on feedback from the fire fighting units. The township map file and computer listing are being used during fire fighting situations to locate the closest suitable water source and access point from the site of a fire. It is expected that this information will increase fire fighting efficiency and, in as many cases as possible, lessen fire damage and reduce consequent property losses.

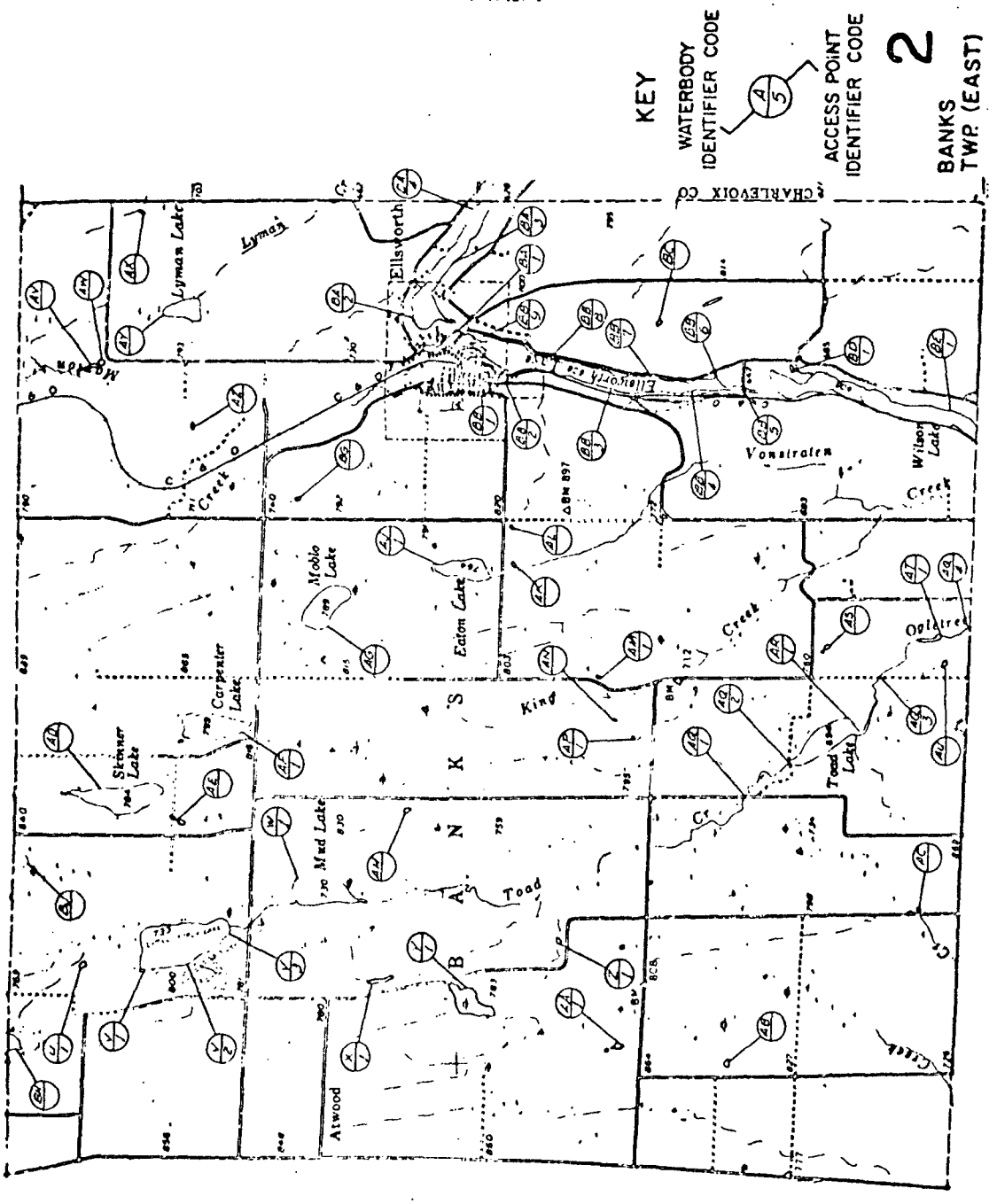

Figure 1. Waterbody/Access Point Map: Banks Twp. (East), Antrim Co.

A3. Agricultural-Use Valuation

Eaton County Equalization Dept.
1045 Independence Boulevard
Charlotte, Michigan 48813

Agricultural Experiment Station
Michigan State University
East Lansing, Michigan 48824

Previous activities of the Remote Sensing Project with the Eaton County Equalization Office involved the development of a prototype analytical system for property tax assessment of agricultural land. The analytical system involves gathering current land use data from remote sensing techniques, and combining this data with soil, slope, and agricultural production data. A final product to the user (in this case, the County Equalization Office) is a detailed map showing land parcel values for 10-acre tracts. These value amounts are then used to develop the current year assessment values.

In the latest semi-annual period, two significant developments occurred with this user application. First, the computer-generated land values were selectively compared with actual assessment values obtained by hand. Very close correlation was found to exist for land parcels over 60 acres, thus indicating the usefulness of the technique. Second, the County Equalization Office has begun to create additional data files for other townships within the County. This commitment on the part of the Equalization Office clearly documents the transfer of a methodology and technique, developed through a NASA-sponsored demonstration, to a permanent procedure within the local agency. The commitment is further demonstrated in that funding for the continuation of this project is being absorbed in the County agency's operating budget, implying that the user finds the procedure a cost effective mode of approaching the problem.

A4. Preservation of the Grand Mere Dune Environment

Grand Mere Association
P.O. Box 140
Stevensville, Michigan 49127

The Grand Mere area, located along the southeast shore of Lake Michigan in Berrien County, and consisting of streams, bogs, lakes, wooded upland, open beaches and dunes, represents one of Michigan's few remaining unique dune environments. The Grand Mere Association is a group of people who have expressed concerns relative to the impact of man on the Grand Mere area in terms of land use changes of parts of the area or adjacent buffer zones and the impact of intensive recreational activities.

Assistance from the MSU Remote Sensing Project was requested for deriving crucial information from remote sensing data on essential ecological parameters affecting the future existence of the Grand Mere area. The most crucial information needed was data documenting the impact of Off-Road-Vehicles (ORV) on the environment, particularly erosion and damage to the vegetation cover of shorelands and dunes on state-owned and private properties.

The loss of vegetative cover between 1970 and 1976 due to ORV activities in two sample areas was determined by a temporal analysis of 1:5,000 panchromatic photography and specially acquired 70mm color photography. Extrapolation of the derived recession rates indicated that if no ORV access limiting measures were taken, complete vegetation loss could occur within one to three decades.

The Grand Mere Association used the photography and derived information to convince property owners and township authorities of the need to prohibit ORV use in the area. In the spring of 1977, an ORV enforcement program was started under a special appropriation of funds for the township police department. Approximately 200 traffic citations were issued during the first two months of the program. The information supplied by the Remote Sensing Project provided a technically sound base and impetus for this legal action.

B. SERVICE ACTIVITIES

Project personnel routinely provide consultation on the use of imagery, educational activities not a part of other user applications, and support materials to foster additional remote sensing applications by prospective users.

The MSU Project team has acted as a service bureau for an increasing number of potential users. To facilitate this function, Project staff have provided general technical assistance, NASA-produced imagery, and training in the use of equipment to a broad range of user agencies.

The type and amount of assistance provided varied among agencies, but has basically included the following activities:

(1) problem identification;
(2) data source identification;
(3) data classification procedures;
(4) identification of decisions that need to be made (policy and action choices);
(5) determining the data needs of various policy and action choices;
(6) assistance in reviewing available imagery;
(7) assistance in acquiring available imagery and equipment;
(8) imagery interpretation training; and
(9) merging remotely-sensed data with other natural resource information.

It is expected that the major benefit to be derived from these service bureau activities is the preliminary education of agencies and individuals to the potential of remote sensing for day-to-day or periodic needs. At an appropriate stage in each agency's program, remote sensing may be the most economical tool to accomplish program objectives.

Furthermore, comparative analysis can be accomplished by effectively merging remotely-sensed land cover/use data with other natural resource information using an integrated, computer-based information system. This provides a powerful tool for regional analysis and the development of appropriate land/resource use decisions and subsequent on-land actions. Such a system is currently under development at MSU and is reported in section B1.

The Remote Sensing Project at Michigan State University is cooperating with Michigan agencies to develop practical uses of remote sensing technology for effective land/resource use decisions and actions. Part of this program is the organization of a centralized source of information on aerial imagery. The Guide to Aerial Imagery of Michigan documents this inventory effort and is described in section B2.

B1. Resource Analysis Program

Activities continue to grow in which the Project utilizes computer-based information systems for storage, analysis, and display of remote sensing and other natural resource data. Larger and larger geographic areas are having natural resource data files being assembled. It is the experience of Project staff that remote sensing derived data form the core of such systems, and combining this data with other data provides an expanded opportunity for users to involve themselves with the dynamics of remote sensing in the role of decision making.

The Project has been developing a computer program for the analysis of grid-based information system data. This period of activity has seen a major revision and improvement in several facets of the Resource Analysis Program (RAP). The analytical and mapping phases required for the agricultural land use assessment technique has been incorporated into the main body of the program (see section A3., this report for further discussion of this application). Internal features of file construction and manipulation have been revised for increased efficiency. A data compression technique is being incorporated that will allow data manipulation for larger geographic areas. Furthermore, this will make RAP directly compatible with various remote sensing data sources, such as Landsat, and merged aerial photography-Landsat data files (see section C3. of this report for further discussion of this latter technique).

As evidence of increased use of this system, an additional 56 townships in Michigan were inventoried and files under a contractual arrangement were created that can now be used with RAP. For additional information, see reference 49 listed in the Appendix.

B2. Guide to Aerial Imagery of Michigan

Preparation of the guide has been a continuing effort for the past two years. It started as a simple revision of an existing guide (Users Guide to High Altitude Imagery of Michigan) but has subsequently developed into an undertaking of considerable magnitude as information on the full range of remotely-sensed imagery available of Michigan has been incorporated into the new guide.

The final draft of the guide has been prepared during this reporting period. The Agricultural Experiment Station at MSU has accepted the guide for publication. A brochure announcing the forthcoming release of the guide was distributed in July 1977 as Research Report 340 of the MSU Agricultural Experiment Station. The Michigan Department of Natural Resources is financially supporting a portion of the publication costs with the remainder paid by the Agricultural Experiment Station. An initial printing of 1,500 to 2,000 copies is being made.

C. CONTRACT ACTIVITIES

Due to Project demonstration activities, there has been an increasing need by public and private agencies within the state for the utilization of remote sensing technology on a periodic project basis. In most cases, however, agencies lack the appropriate equipment and the photo interpretative skill to meet the need. They usually do not retain staff with photo interpretation expertise because their services are not needed on a continual basis. However, most agencies would like to have a means of acquiring such skills for limited periods to complete specific projects. MSU has the capability to meet this need through either a contractual or student support basis due to the development of on-campus faculty and student remote sensing expertise by Project personnel.

All of the contract activities have occurred as a direct spin off from Project demonstration activities and demonstrate the commitment of funds by other agencies to the use of remote sensing. They have been included in this report in order to substantiate the repetitive need for photo-derived information and the operational capability of previously demonstrated remote sensing procedures for specific data acquisition needs.

C1. Comprehensive Resource Inventory and Evaluation System (CRIES) Project

The contract with the U.S. Department of Agriculture, Economic Research Service (ERS) continued throughout this reporting period. Three significant areas of activity were investigated: development of geocoding methods for large geographic areas, generating data for economic planning by visual interpretation of Landsat imagery, and development of techniques for creating land information systems for country-wide planning.

A manual technique has been developed by which large area maps can be digitized at a relatively low cost. The technique involves little advanced technology, and so is highly suitable for the eventual transfer to the developing countries in which the CRIES project is currently operating. The technique involves not only the data digitization stage, but also methods for verification, correction, and mapping using small, inexpensive computers.

The Landsat demonstration for country-wide economic planning was nearly complete at the end of the reporting period. Four test sites within the Dominican Republic were visually interpreted for eleven land cover categories. Two of these sites were also being digitally interpreted by Intralab at NASA, Goddard, in order to provide a basis of comparison for continued use by Dominican technicians. Initial field checking verified the accuracy of the visual interpretation to a highly acceptable degree.

Information system development entered the prototype stage during this reporting period. Nine thematic maps of the Dominican Republic (scale 1:250,000) were entered into the land data system. The maps represented a wide variety of data types and formats. These data were selected by CRIES project economists as being essential to the overall project development. Geographic data for each map covered an area exceeding 100,000 km^2.

C2. Unique Farmlands Inventory

Soil Conservation Service
U.S. Department of Agriculture
1405 South Harrison Road
East Lansing, Michigan 48824

The Soil Conservation Service contracted with the MSU Project for the identification of unique farmland areas, new water areas, and new urban built-up areas that are not delineated on the published soil survey sheets for Lapeer, Macomb, Muskegon, St. Clair and Washtenaw Counties in Michigan. The inventories were derived from either panchromatic or NASA high altitude color-infrared aerial photography flown in 1975. All water, urban built-up, and unique farmland areas more than 10 acres in size were identified and delineated through manual interpretation of the aerial photography. Unique farmlands are lands other than those designated prime that are used for the production of specific high-value food and fiber crops (e.g. tree and bush fruits, vineyards and vegetables).

The final product was a set of soil survey atlas sheets (maps) for each county indicating water, urban built-up and unique farmland areas. The data satisfies part of the Land Inventory and Monitoring (LIM) program of the U.S. Department of Agriculture and the SCS for the counties. Under this program, prime farmlands will also be delineated, area calculations per category will be estimated and a final Important Farmlands Map will be produced for each county.

C3. Region V Land Cover/Use Inventory

Region V GLS
100 Phoenix Building
801 South Saginaw Street
Flint, Michigan 48502

Bendix Corporation
Aerospace Systems Division
3621 South State Road
Ann Arbor, Michigan 48107

The Bendix Corporation, Aerospace Systems Division sub-contracted with the MSU Project for the provision of certain data products and services in support of a land cover/use inventory for the Region V Planning and Development Commission of Genesee, Lapeer, and Shiawassee Counties, Michigan. Project personnel identified, to a 5-acre level of detail, eight urban land use categories from high altitude CIR photography. The urban category delineations were digitized and subsequently integrated with computer categorized Landsat data processed on the Bendix M-DAS system. MSU used the digital multi-source data files to produce 1:24,000 computer-generated plotter maps on mylar for each of the 52 townships in the region. Three county maps (1:48,000) were then produced through photographically reducing and merging individual township maps.

This contract was a direct spin off from a merging procedure developed jointly by the Project under the NASA grant and by the Bendix Corporation (reported in the previous Semi-Annual Progress Report, June 1976-November 1976 and reference #50 in the Appendix of this report).

C4. Tri-County Natural Resources Information System

Tri-County Regional Planning Commission
2722 East Michigan Avenue
Lansing, Michigan 48912

The MSU Project prepared a grid geocoded natural resource information file for Bath, Delhi, Dewitt, and Watertown Townships in Michigan under a contract from the Tri-County Regional Planning Commission. Land use, soils, and elevation data were recorded for each 10-acre cell of the townships from the 1972 Tri-County Land Use/Cover Inventory maps derived from NASA high altitude color-infrared aerial photography, the county soil survey map, and U.S.G.S. topographic quandrangles, respectively.

A scaled, 10-acre cell grid was superimposed and registered to each data source map. The dominant factor (e.g. land use) in each cell and the cell identifier codes (row/column coordinates) were recorded on computer coding forms. The township data were then keypunched, verified, and encoded on a tape file.

A computer program transposed the initial data symbol codes into numeric sequence codes that allow subsequent analysis of the data using the Resource Analysis Program (RAP). Sequence codes were determined for soil management group, slope, drainage and land use.

The final product was a machine-readable card data deck for each of the four townships. Each data record (card image) contained: 1) county identifier code, 2) township identifier code, 3) row and column coordinate, 4) soil symbol, 5) soil management group number, 6) soil management group code, 7) slope code, 8) drainage code, 9) land use symbol, 10) land use code, and 11) the elevation of that 10-acre cell.

A p p e n d i x

P U B L I C A T I O N S a n d P R E S E N T A T I O N S

. . . . . of the Michigan State University Project

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1. "Investigation of Land Resource Use in Southeast Michigan." J. G. Ahl, M. G. Boylan, D. L. Mokma, W. L. Myers, S. W. Schar and R. D. Vlasin. Proceedings of the Eighth International Symposium on Remote Sensing of Environment. pp. 23-33. Environmental Research Institute of Michigan. Ann Arbor, Michigan. October 1972.

2. Remote Sensing in Michigan for Land Resource Management: Highway Impact Assessment. Environmental Research Institute of Michigan. Ann Arbor, Michigan. December 1972. 107 p.

3. Users Guide to High Altitude Imagery of Michigan. Mark C. Sullivan and Stephen W. Schar. Michigan State University. East Lansing, Michigan April 1973. 39 p.

4. Proposed Land Use Classification System. Project for the Use of Remote Sensing in Land Use Policy Formulation. Michigan State University. East Lansing, Michigan. July 1973. 26 p.

5. Proceedings of the Conference on Practical Applications of Remote Sensing. (May 15-16). Ken Keifenheim and Stephen W. Schar, Editors. Michigan State University. East Lansing, Michigan. September 1973. 72 p.

6. Image Interpretation for a Multi-Level Land Use Classification System. Mark C. Sullivan and Gary Higgs. Michigan State University. East Lansing, Michigan. September 1973. 35 p.

7. The Use of Color Infrared Photography for Wetlands Mapping: With Special Reference to Shoreline and Waterfowl Habitat Assessment. William R. Enslin. Michigan State University. East Lansing, Michigan. October 1973. 33 p.

8. Upper Kalamazoo Watershed Land Cover Inventory. Benjamin Richason III and William R. Enslin. Michigan State University. East Lansing, Michigan. October 1973. 39 p.

9. "A Comparative Analysis of Remote Sensing Scale/System Attributes for a Multi-Level Land Use Classification System." Mark C. Sullivan and Gary Higgs. Proceedings of the American Society of Photogrammetry Fall Convention. pp. 335-367. American Society of Photogrammetry. Falls Church, Virginia. October 1973.

10. Evaluating Data Collection Costs with Emphasis on Remote Sensing. Marilyn J. Bennett. M.S. Thesis, (unpublished). Michigan State University. East Lansing, Michigan. 1974. 146 p.

11. "Focus on Community Development." Michigan Science in Action. Report No. 26. Michigan State University Agricultural Experiment Station. East Lansing, Michigan. February 1974.

12. "Resource Inventory for Multi-Agency Watershed Planning." W. R. Enslin, B. Richason III and M. J. Bennett. Remote Sensing of Earth Resources. Volume III. pp. 653-670. The University of Tennessee Space Institute. Tullahoma, Tennessee. March 1974.

13. "The Use of Color Infrared Photography for Wetland Assessment." William R. Enslin and Mark C. Sullivan. Remote Sensing of Earth Resources. Volume III. pp. 697-720. The University of Tennessee Space Institute. Tullahoma, Tennessee. March 1974.

14. "Operational Remote Sensing for Land Capability Analysis of Michigan." Myles G. Boylan and Stephen W. Schar. Presented at Michigan Academy of Science, Arts and Letters. Environmental Studies Section. Michigan State University. East Lansing, Michigan. March 1974.

15. "A Quick Procedure for Developing Environmental Planning Inventories in Michigan." Stephen W. Schar. Presented at Michigan Academy of Science, Arts and Letters. Environmental Studies Section. Michigan State University. East Lansing, Michigan, March 1974.

16. "Color-Infrared Airphotos as a Source of Forest Resource Data for Regional Information Systems: Putting Remote Sensing Technology to Work in Northwestern Michigan." William D. Hudson and Wayne Myers. Presented at Michigan Academy of Science, Arts and Letters. Environmental Studies Section. Michigan State University. East Lansing, Michigan. March 1974.

17. "Collection and Manipulation of Land Use Information for Corridor Analysis." Mark C. Sullivan. Presented at Michigan Academy of Science, Arts and Letters. Environmental Studies Section. Michigan State University. East Lansing, Michigan. March 1974.

18. Remote Sensing in Michigan for Land Resource Management: Waterfowl Habitat. A. N. Sellman, I. J. Sattinger, L. B. Istvan, W. R. Enslin, W. L. Myers, M. C. Sullivan. Environmental Research Institute of Michigan. Ann Arbor, Michigan. April, 1974. 43 p.

19. "Resource Analysis Applications in Michigan." S. W. Schar, W. R. Enslin, I. J. Sattinger, J. G. Robinson, R. S. Fellows, K. R. Hosford and J. G. Raad. Summaries of the Ninth International Symposium on Remote Sensing of Environment. pp. 236-237. Environmental Research Institute of Michigan. Ann Arbor, Michigan. April 1974.

20. "Design Concepts for Land Use and Natural Resources Inventories and Information Systems." R. L. Shelton and E. E. Hardy. Summaries of the Ninth International Symposium on Remote Sensing of Environment. pp. 53-54. Environmental Research Institute of Michigan. Ann Arbor, Michigan. April 1974.

21. "Resource Analysis Applications in Michigan." S. W. Schar, W. R. Enslin, I. J. Sattinger, J. G. Robinson, R. S. Fellows, K. R. Hosford, and J. G. Raad. Proceedings of the Ninth International Symposium on Remote Sensing of Environment, Vol. III, pp. 2073-2081. Environmental Research Institute of Michigan. Ann Arbor, Michigan. April 1974.

22. "Design Concepts for Land Use and Natural Resources Inventories and Information Systems." Ronald L. Shelton and Ernest E. Hardy. Proceedings of the Ninth International Symposium on Remote Sensing of Environment. Vol. I. pp. 517-536. Environmental Research Institute of Michigan. Ann Arbor, Michigan. April 1974.

23. Determining Regional Soil Losses Resulting from Construction Activities. S. E. Tilmann, D. L. Mokma and R. L. Stockman. Project for the Use of Remote Sensing in Land Use Policy Formulation. Michigan State University. East Lansing, Michigan. January 1975. 21 p.

24. "Improved Resource Use Decisions and Actions through Remote Sensing." M. Boylan, W. R. Enslin, R. Hill-Rowley and R. D. Vlasin. Abstracts of the NASA Earth Resources Survey Symposium. pp. 231-233. Johnson Space Center. Houston, Texas. June 1975.

25. Michigan Land Cover/Use Classification System. Michigan Land Use Classification and Referencing Committee. Office of Land Use, Department of Natural Resources. Lansing, Michigan. July 1975. 60 p.

26. "Improved Resource Use Decisions and Actions Through Remote Sensing." R. Hill-Rowley, M. Boylan, W. Enslin and R. Vlasin. Proceedings of the NASA Earth Resources Survey Symposium. Vol. IC. pp. 1747-1767. Johnson Space Center. Houston, Texas. September 1975.

27. "Improved Resource Use Decisions and Actions Through Remote Sensing." M. Boylan, W. R. Enslin, R. Hill-Rowley and R. D. Vlasin. Summaries of the Tenth International Symposium on Remote Sensing of Environment. pp. 112-113. Environmental Research Institute of Michigan. Ann Arbor, Michigan. October 1975.

28. "Survey of Recent Resource Applications in Michigan." W. C. Taylor, W. R. Enslin, C. E. Olson, Jr., and I. J. Sattinger. Summaries of the Tenth International Symposium on Remote Sensing of Environment. pp. 123-125. Ann Arbor, Michigan. October 1975.

29. "Improved Resource Use Decisions and Actions through Application of High Altitude Color-Infrared Imagery." W. R. Enslin, M. Boylan. R. Hill-Rowley and R. D. Vlasin. Proceedings of Applications of Remotely-Sensed Data in North Central United States. p. 35. American Institute of Aeronautics and Astronautics and Bendix Aerospace Systems Division, Ann Arbor, Michigan. November 1975. (Abstract).

30. "Improved Resource Use Decisions and Actions Through Remote Sensing." M. Boylan, W. R. Enslin, R. Hill-Rowley and R. D. Vlasin. Proceedings of the Tenth International Symposium on Remote Sensing of Environment. pp. 793-801. Environmental Research Institute of Michigan. Ann Arbor, Michigan. October 1975.

31. "Survey of Recent Resource Applications in Michigan." W. C. Taylor, W. R. Enslin, C. E. Olson Jr., and I. J. Sattinger. Proceedings of the Tenth International Symposium on Remote Sensing of Environment. pp. 857-865. Environmental Research Institute of Michigan. Ann Arbor, Michigan. October 1975.

32. "Remote Sensing of Abandoned Vehicles for County Planning," Salleh M. Nor. Remote Sensing of Earth Resources, Vol. V, edited by F. Shahrokhi, The University of Tennessee Space Institute, Tullahoma, Tennessee, 1976. (In Press).

33. "Improved Land Use Decisions and Actions in Michigan Through Remote Sensing." Richard Hill-Rowley and William R. Enslin. Proceedings of the Association of American Geographers, Vol. 8. pp. 132-136. Association of American Geographers, Washington, D. C. April 1976.

34. "Remote Sensing for Identifying Essential Lands." William R. Enslin. Presented at the Fourth Annual Michigan Land Use Policy Conference. Michigan State University, East Lansing, Michigan. April 1976.

35. "Report on the Land Use/Cover Map and Soil Limitations Maps for the 1865 Treaty Lands of the Saginaw-Chippewa Indian Tribe." NASA Remote Sensing Project, Michigan State University, East Lansing, Michigan. May 1976, 19 p. (Mimeographed).

36. "Soil Management Groups: A useful tool for interpretive and glacial maps." S. E. Tilmann and G. Larson. Presented at the North-Central meeting of the Geological Society of America, Kalamazoo, Michigan. April 1976.

37. "Evaluating limitations to ground water recharge by a multi-dimensional scaling model." S. E. Tilmann. Presented at the North-Central meeting of the Geological Society of America, Kalamazoo, Michigan. April 1976.

38. "A Strategy for Land Use/Cover Data File and Map Preparation." Stephen E. Tilmann and Robert H. Rogers. Bendix Aerospace Systems Division. Ann Arbor, Michigan. May 1976. 21 p. (Mimeographed).

39. "1972 Land Cover/Use Inventory of Clinton, Eaton and Ingham Counties, Michigan." Remote Sensing Project, Michigan State University, East Lansing, Michigan. June 1976. 49 p. (Mimeographed).

40. "Report on the Natural Resource Information System Developed for the Tri-County Regional Planning Commission." Remote Sensing Project, Michigan State University, East Lansing, Michigan. July 1976. 95 p. (Mimeographed).

41. "Identifying and Mapping Forest Resources From Small-Scale Color Infrared Airphotos." W. D. Hudson, R. J. Amsterburg Jr., and W. L. Myers. Michigan Agricultural Experiment Station Research Report 304. Michigan State University, East Lansing, Michigan. July 1976. 12 p.

42. "Documentation: 1970 SEMCOG Land Use Inventory." Johnson, Johnson and Roy, Inc. Ann Arbor, Michigan. July 1976. 22 p. (Mimeographed).

43. "Engineering properties of soil management groups." S. E. Tilmann and D. L. Mokma. Michigan Agricultural Experiment Station Research Report 313. Michigan State University, East Lansing, Michigan. August 1976. 12 p.

44. "Soil management groups and soil erosion control." S. E. Tilmann and D. L. Mokma. Michigan Agricultural Experiment Station Research Report 310. Michigan State University, East Lansing, Michigan. August 1976. 16 p.

45. "Mapping of Remote Sensing Data for Michigan Agencies." Kenneth E. Keifenheim. Presented at the East Lakes Division Meetings, Association of American Geographers, Ann Arbor, Michigan. October 15, 1976.

*46. "Keeping Our Resources Under Surveillance." Laurie De Firmian and Roberta Yafie. Supplement to the Michigan State University Alumni Magazine, Vol. 2, No. 4. pp. 4-5. College of Agriculture and Natural Resources, Michigan State University, East Lansing, Michigan, Nov./Dec. 1976.

*47. "MSU Remote Sensing Project" in 89th Annual Report, Agricultural Research in the Bicentennial Year Research Report 319. pp. 13-15. Agricultural Experiment Station, Michigan State University, East Lansing, Michigan. December 1976.

*48. "Michigan Resource Inventories: Characteristics and Costs of Selected Projects Using High Altitude Color Infrared Imagery." W. R. Enslin and R. Hill-Rowley. Presented at the First Conference on the Economics of Remote Sensing Information Systems, San Jose State University, San Jose, California. January 1977.

*49. "A Computer Software System for Integration and Analysis of Grid-Based Remote Sensing Data with Other Natural Resource Data." S. E. Tilmann, W. R. Enslin, and R. Hill-Rowley. Proceedings of the 43rd Annual Meeting of the American Society of Photogrammetry. pp. 3-14. American Society of Photogrammetry, Washington, D.C. February 1977.

*50. "A Procedure for Merging Land Cover/Use Data from Landsat, Aerial Photography, and Map Sources: Compatibility, Accuracy and Cost." W. R. Enslin, S. E. Tilmann, R. Hill-Rowley, and R. H. Rogers. Proceedings of the 43rd Annual Meeting of the American Society of Photogrammetry. pp. 449-458. American Society of Photogrammetry, Washington, D.C. February 1977.

*51. "Estimation of Old Field Ecosystem Biomass Using Low Altitude Imagery." Salleh Mohd. Nor, Gene Safir, T. M. Burton, J. E. Hook and G. Schultink. Summaries of the 11th International Symposium on Remote Sensing of Environment. p. 85. ERIM, Ann Arbor, Michigan. April 1977.

*52. "Application of Aerial Photography to Water-Related Programs in Michigan." W. R. Enslin, R. Hill-Rowley and S. E. Tilmann. Summaries of the 11th International Symposium on Remote Sensing of Environment. pp. 100-101. ERIM, Ann Arbor, Michigan. April 1977.

*53. "Estimation of Old Field Ecosystem Biomass Using Low Altitude Imagery." Salleh Mohd. Nor, Gene Safir, T. M. Burton, J. E. Hook and G. Schultink. Presented at the 11th International Symposium on Remote Sensing of Environment. ERIM, Ann Arbor, Michigan. April 1977.

*54. "Application of Aerial Photography to Water-Related Programs in Michigan." W. R. Enslin, R. Hill-Rowley and S. E. Tilmann. Presented at the 11th International Symposium on Remote Sensing of Environment. ERIM, Ann Arbor, Michigan. April 1977.

*55. "Characteristics of Remote Sensing Applications in Michigan." Richard Hill-Rowley and William R. Enslin. Presented at the 73rd Annual Meeting of the Association of American Geographers. Salt Lake City, Utah. April 25, 1977. (Mimeographed).

*56. "The Acquisition and Integration of Land Use Data for Regional Planning." Richard Hill-Rowley and William R. Enslin. Presented at the 3rd Symposium of the American Institute of Aeronautics and Astronautics on the Applications of Remotely Sensed Data. Ann Arbor, Michigan. May 1977.

* Published or presented during this reporting period.